Modelling international freight traffic with a particular focus on access transport to a peripheral island

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ABSTRACT

The freight transport system under consideration is the system linking Ireland (Northern Ireland and the Republic of Ireland) with Great Britain and the remainder of the EU. The aims of the research are to develop a means of predicting future transport demand on that system under alternative scenarios. The approach uses an econometric method in addition to which estimates of environmental implications of the strategies are also made. The results include outputs on demand levels, modal split, environmental impact and economic benefits and indicate that an 'ideal' strategy would combine some form of demand restraint and selected infrastructural improvements rather than a singularly 'high investment' or a 'managed demand' strategy.

BACKGROUND

Interregional freight modelling requires that a number of specific issues be taken into consideration. Many assumptions in the field of transport demand modelling are still rooted in the characteristics of urban passenger demand. Particular issues related to freight modelling include the additional difficulties of obtaining calibration information and of dealing with the varying characteristics of different commodities involved in freight demand prediction. There is a particularly acute problem in obtaining detailed calibration information for freight in the Irish access market.

A four-stage (generation-distribution-modal split-assignment) methodology similar to the classical passenger transport model is sometimes adopted in freight transport demand models, although alternatives to the four-stage model are probably more widely used in freight than passenger modelling. Ortúzar and Willumsen (1994) outline a variety of methodologies for freight trip generation. These include direct surveys of demand and supply (for homogeneous commodities produced on a large scale, such as coal or cement), macroeconomic models, growth factors, zonal multiple linear regression and (in urban areas) warehouse or retail floor areas in a zone.

In respect of freight trip generation, Friesz et al. (1983) observed that most freight network models in use at that time utilised exogenously determined supplies and demands, typically generated from macroeconomic models. It was considered that this situation could lead to contradictions arising between the outputs of the econometric model (which assumed a greatly simplified transport network) and the detailed network model. Models with endogenous trip generation, typically based on spatial price equilibrium, were therefore seen as superior.

Bayliss (1973) describes the Northeast Corridor Project's "inventory theoretic model"; this is based on the assumption that shippers treat freight in transit similarly to a stationary inventory of stock. Bayliss further observes that the degree of approximation involved appears to have invalidated the bulk of the inventory-based model's innovations, effectively reducing it to a traditional model based upon costs and times.

Gray (1982) divides freight modal split models as existing at that time into three principal categories. The first is based on so-called "economic positivism", whereby a firm's economic variables (e.g. marginal revenue) determine its choice of mode. The second is "technological positivism"; this relates the physical attributes of the mode to those of the consignment. Finally, the "perceptual approach" is based, as its name implies, on the subjective perceptions of the individual (e.g. a transport manager) making the decision.

Ortúzar and Willumsen (1994) describe freight assignment methods as being generally of a stochastic all-or-nothing nature, some examples making use of multi-class techniques to represent the varying characteristics of vehicle and commodity types. It may be that the situation under study would be amenable to the use of a combined modal split and assignment model - e.g. a hierarchical logit model, with choice of mode for the sea crossing being handled at a higher level than choice of route, and choice of access/egress mode at a lower level again. Indeed, KPMG and CHL's (1990) analysis of the structure of unitised freight transport choices appears to support this contention.

Safwat and Magnanti (1988) describe the STEM (Simultaneous Transportation Equilibrium Model) which combines all four stages of the classical model into one, equilibrium being reached by solution of an "equivalent convex program", typically via a variant of the Frank-Wolfe algorithm. STEM's first application was in an interregional passenger study. This was carried out in Egypt, focusing on low-income passengers and considering four modes (taxi, bus, local train, express train); it was apparently successful in both computational and behavioural terms. To date, there have been relatively few applications of this model. Nevertheless, it appears to have been relatively effective, and was retained for further examination in the context of this study. Although the characteristics of Safwat and Magnanti's STEM (1988) methodology might appear to offer similar advantages in freight demand modelling as in passenger, its use in this field has been even more restricted.

Moavenzadeh et al. (1983) describe the use of STEM in the Egyptian Intercity Transportation Planning Model, including both passenger and freight components. Again, the model appears to have performed satisfactorily. Further novel features of the Egyptian methodology included simulation models of link costs (rather than closed-form functions) and the application of fleet capacity constraints in addition to link congestion.

The STAN model (INRO 1997) was used for certain freight transport case studies in the EU funded project STEMM, specifically those relating to freight flows to and from Scandinavia across the North Sea and via the Scan-Link (Sweden-Germany) corridor. Several features are common to both STAN and the urban/regional passenger model EMME/2.

STAN owes something to both sequential and simultaneous model forms. Trip generation is exogenous; this can be by means of an econometric model. Trip distribution can be performed according to any rule (e.g. entropy, Fratar) compatible with the model's two-dimensional matrix balancing procedure. An unusual feature is the provision of a three-dimensional balancing procedure for cases where trips are stratified by a further factor other than origin and destination (e.g. screenline crossings, travel impedance intervals). The model then proceeds sequentially to the next stage.

This stage is a simultaneous modal split and assignment process; thus, STAN could be described as a three-stage model with two simultaneous stages within the second stage of a two-stage sequential process. The theoretical basis of this type of model is outlined by Ortúzar and Willumsen (1994). Freight flows are assigned to multi-modal paths in such a way as to achieve Wardrop system optimal assignment; solution is by the Frank-Wolfe algorithm. Specific enhancements to STAN were developed for the STEMM case studies.

In the Scan-Link case study (VTT 1998), a network with 158 zones was developed, representing Norway, Sweden, Finland, Denmark and Ireland at NUTS3 (NUTS - Nomenclature of Units for Territorial Statistics - is a hierarchical classification of areas that provides a breakdown of the EU's economic territory level) (in Ireland's case, the planning regions). Benelux, France, Germany and the UK were zoned at NUTS1 (the statistical regions in the case of the UK) and the remainder of Europe at one zone per country, with six "rest of the world" zones. A road, rail and water transport network was developed at varying levels of detail (highest in Scandinavia, lowest on the periphery of Europe). Nine modes (road, rail, fast rail, truck ferry, rail ferry, sea bulk, lo-lo, inland waterway, car/truck ferry) were represented. A new commodity classification was derived for the purposes of the case study, based on the Standard International Trade Classification (SITC). Three cost functions for each link represented operating cost, logistics performance (risk of damage, reliability) and frequency. Calibration was by comparison of volumes and mode shares with observed results. Trip generation was by a dedicated "STEMM Freight Flow Model".

In constructing the cost functions, weights were derived from Finnish customs statistics and ITS Leeds surveys for six factors (risk of damage, reliability, inventory cost, operating cost, lead time, frequency) in the case of each of the twelve commodity groups in the classification used. While the NITL (1999) cost factors are not entirely identical, the weights used in STEMM do appear to correspond relatively well to Irish conditions.

For the purposes of the Nordic/North Sea case study in STEMM (SINTEF et al. 1998), the same modes and network as in the Scan-Link case study were applied but commodity groups restricted to fertiliser, meat, fish and fruit/vegetables.

The MDST model (Baxter Eadie et al. 1999) was developed especially for STEMM by MDS Transmodal. It is essentially a generalisation- both in spatial and modal terms- of an earlier model of truck traffic across the English Channel. The STEMM project saw MDST applied to multi-modal case studies of both cross-Channel and trans-Alpine freight traffic.

Generation and distribution are not carried out within the transport model but via a separate trade forecasting model. Mode and route choice in the MDST model are handled by a modified multinomial logit model which takes account of the degree of similarity between competing options but (unlike hierarchical models) contains only one level of choice.

THE FREIGHT MODEL

A review of all of the models mentioned above led to a final shortlist of just two models, MDST and STAN. A feature of the MDST model was that it was developed from a cross-Channel model and generalised to apply to any "crossing" situation- the example in STEMM being the Alpine crossing. This would imply suitability for Irish applications; however, it is not clear whether it necessarily implies greater suitability than STAN. The latter was employed in STEMM case studies of freight traffic across the North Sea and on the Scan-Link corridor (Germany-Sweden); both of these involve crossings of a significant water barrier and thus resemble the Irish Sea situation. There was no reason to suppose from the results of the various case studies that STAN experienced any problems in representing and analysing such a situation.

In terms of compliance with the basic technical requirements which have emerged from the review, both models appear to perform well. Both can represent complex multi-modal networks. The MDST model was to have incorporated an allowance for the longer term effects of new infrastructure on freight flow patterns, but it was not possible to develop this within the STEMM project. As they stand, therefore, both models rely on exogenous trip generation. Unlike the passenger situation, there is no evidence to believe that transport changes have a significant immediate effect on the overall volumes of freight movements in the Irish access market. Therefore, the sacrifice involved in accepting a trip generation format that did not respond to changes in transport supply would not be unacceptably large.

Calibration requirements were considered important to the choice of model format; however, different model types were not always found to have significantly differing requirements (Whitney, 2002).. The situation with regard to the choice between MDST and STAN was somewhat different. In this case, the STEMM project had shown that STAN could be successfully implemented with a simplified calibration methodology (STEMM Freight Flow Model), as used in the Scan-Link case study. The position with regard to MDST was less clear; in the cross-Channel case study at least, the model had been calibrated on data from surveys. Such resources would not be available to the present project, and the surveys carried out for STEMM had anyway proved less adequate than might have been desired in some respects.

On the basis of the formats of the two models as they were employed in STEMM (making no allowance for any possible future enhancements), STAN appeared superior on grounds of ease of calibration and a more extensive record of successful applications. There did not appear to be much to choose between the two models on other matters.

MODEL SPECIFICATION

The model chosen for modal split and assignment purposes is the STAN model. Freight flows in STAN are assigned to multi-modal paths in such a way as to achieve Wardrop system optimal assignment; solution is by the Frank-Wolfe algorithm. The assignment problem is expressed mathematically as:

Minimise: $F = \sum_{p \in P}(\sum_{a \in A} s_a^p(v)v_a^p + s_t^p(v)v_t^p)$ Eqn 1

subject to: $h_k = g_{od}^m(p)$

$o \in O, d \in D, m(p) \in M(p), p \in P$

$h_k \geq 0, k \in K$

where: F	=	total generalised system cost.
p	=	product (commodity).
P	=	set of products (commodities).
a	=	arc (link).
A	=	set of all arcs.
s	=	cost function.
v^p	=	flow volume of product *p* on network.
t	=	transfer (i.e. between 2 modes).

T	=	set of all transfers.
m	=	mode.
M	=	set of all modes.
$M(p)$	=	set of all allowable modes for particular product.
$g_{od}^{m}(p)$	=	total demand for transport of a product.
k	=	path.
K	=	set of all paths.
$K_{od}^{m}(p)$	=	set of paths from origin o to destination d.
o	=	origin.
d	=	destination.
O	=	set of all origins.
D	=	set of all destinations.

Although matrices from the Scan-Link STEMM case study were made available to the author, these included only trade flows to or from the Nordic countries of Iceland, Denmark, Sweden, Norway and Finland. Therefore, the majority of flows would have to be derived from some other source.

A decision in principle was taken to use OD-ESTIM (Burgess, 2002) to predict freight flows in future years, since (without a trade forecasting model) the STEMM Freight Flow Model is insufficient for this purpose. The aim of the project, from which OD-ESTIM was an output, was to develop a cost-efficient method for developing region-to-region transport matrices of flows based upon the economic values of the regions involved. The premise is that the economic information is often accessible, whilst transport flows measurements are missing. This was subsequently modified to the development of a regression model from Irish commodity flow data (the "external trade by ports" statistics published until 1993; CSO 1993). OD-ESTIM itself was of limited use because it had been calibrated on a different commodity classification.

The zonification used in the Scan-Link case study was considered adequate for the requirements of the present work. The key areas-Ireland, UK, France, Benelux, Germany- are covered at a good level of regional detail in this system, and the coverage of the rest of Europe is more than adequate. The one alteration desired was to aggregate the Scandinavian countries to one zone per country (comparable to the rest of Europe outside Ireland/UK/France/Benelux/Germany) because there was no obvious benefit in representing them at a higher level of detail for the purposes of an Irish-based study. In addition, aggregation of the very complex Scandinavian network in the original data bank was necessary in order to reduce the system to a size manageable for the version of STAN used by the author.

The modal classificatio n utilised in the Scan-Link study was considered appropriate for the Irish access market, with certain exceptions. "Rail ferry" and "inland waterway" (mode "i") networks were considerably reduced in size from the STEMM originals, and the rail ferry network eventually removed, but residual inland waterway links allowed to remain where they were of relevance. Two modes- air freight and fast car/truck ferry- were considered for addition to the list in order to better represent the characteristics of the Irish access transport system. It was decided to incorporate air freight (mode "A") into the 1995 base system, but not fast ferries, as no fast ferry services capable of conveying freight existed on Irish routes until 1996.

The modes in the 1995 network were therefore, Truck (mode "l"), Rail (mode "r"), Lo-lo (mode "a"), Bulk ship (mode "b"), Inland waterway (mode "i"), Ferry (mode "f"), Air freight (mode "A"). The following new modes were added in one or more of the 2020 strategies: Fast ferry (mode “s”), High-speed (lo-lo) freight vessel (mode “H”) and Truck on piggyback rail or fixed-link rail shuttle (mode “p”).

CALIBRATION

A calibration process was carried out by those responsible for constructing the STAN network used for the STEMM Scan-Link case study. According to VTT (1998), the assignment results were compared with observed traffic volumes in Finnish ports and the rail and road network and they were found to be quite close to each other. A more specific examination of the Irish situation was also made to ensure calibration was complete.

Figure 1 summarises trends in the demand for freight transport in the Irish access market over recent years. A significant overall volume growth will be noted; however, lo-lo traffic has grown far more sluggishly than ro-ro, and indeed has been nearly static over part of the period. A situation of approximately equal demand for ro-ro and lo-lo services has gradually given way to one where ro-ro demand is roughly 33% higher than lo-lo demand. It is likely that such changes are attributable to trends towards higher-value commodities (putting a premium on the speed and reliability of ro-ro shipping) and changes in the logistical backdrop for all commodity movements, in particular the growth of “just-in-time” delivery, again necessitating a swift, reliable service which lo-lo has problems in delivering.

Freight modal split was one of the issues covered by the Transport Policy Research Institute (TPRI) (1995). In this report, Irish manufacturers were divided into a number of sectors; in each case, the sector’s locations within Ireland, principal export markets, characteristics of products and priorities in selecting a mode were considered. This study suffers from the disadvantage (from the point of view of the present work) that it did not cover freight flows other than those generated by the Irish manufacturing industry; nevertheless, for those flows within its terms of reference, it is of use in many respects. It must also be noted that worldwide exports were also covered by the study, although, in practice, the UK, France, Benelux and Germany dominated the markets in the case of most sectors.

The approach adopted was to identify the key transport-using sectors of manufacturing industry. This was done using a composite indicator based on employment, total import/export value, net export value, sales and expenditure in the Irish economy. Ten principal sectors were identified (a) office computers/data processing machinery (b) pharmaceutical products (c) dairy products (d) service industry products (principally software) (e) 'other food products' (including food ingredients, tinned foods, convenience foods and mushrooms, but not meat, dairy products, or general fruit and vegetables) (f) parts/accessories for motor vehicles (g) healthcare products/medical equipment (h) telecommunications/electronic equipment (i) meat products (j) basic industrial chemicals.

The transport characteristics of these sectors are described in Table 1. The principal observations on the individual sectors are that;

(a) 'the key transport issue' for most *computer products* is speed. Quality of service, particularly security and avoidance of damage, is more important than cost. Large shipments travel mainly ro-ro and smaller by express groupage (e.g TNT, UPS), the latter often using air transport. The main destinations are the UK, France, the Netherlands and Germany; products are often distributed to EU markets via depots in these countries;

(b) that *pharmaceutical* exports are widely dispersed throughout the world, the EU accounting for only 53.7%; within the EU, the UK/Benelux/French/German markets dominate. Bulk products are shipped lo-lo, in tank containers if in liquid form, while high value, low volume products travel by ro-ro or air express groupage service. Timeliness and speed are the key issues;

(c) that the characteristics of *dairy product* exports vary according to the perishability of the product in question. Most exports consist of butter, cheese, milk solids etc., which have a long shelf life. These generally travel by lo-lo, sometimes refrigerated. Some perishable products such as yoghurt and fresh cheeses are exported by refrigerated ro-ro, but only on a limited scale. In general, cost is more important than speed; that *software* exports are not easily broken down by destination. Fragility is an important factor, but this is complicated by the bulky, low-value manuals shipped with the products. Price is less important than quality of service. There is some limited use of telecommunications for distributing one-off products to users; most exports appear to be by ro-ro;

(d) that *'other food products'* are not, in general, particularly perishable. Cost therefore dominates over speed, although timeliness is also very important. Most products in this sector travel lo-lo. *Mushrooms* are a special case; they are highly perishable and their export market is effectively confined to the UK. Shipment to Britain was originally by air, but improved surface transport now makes it possible for the products to travel by ro-ro;

(e) that the *motor parts* industry relies heavily on just-in-time (JIT) logistics, requiring frequent door-to-door deliveries. Although ro-ro would be ideal in terms of speed and reliability, it is too expensive to use for all shipments, given their low density. Consequently, the bulk of exports move by lo-lo, with a backup flow by ro-ro to maintain frequent, reliable delivery. The influence of freight forwarders appears significant in this sector. The need for frequent shipments is the dominant factor, but timeliness is also of importance;

(f) that the range of products described as *'healthcare products and medical equipment'* is very wide and thus transport requirements also vary. High volume consignments travel by lo-lo and high value/low volume ones by air. Speed requirements vary, but generally deliveries to end-users are more critical (because holdings of stock are smaller and thus orders tend only to be made when stocks run low) than those to retail/wholesale customers;

(g) that *telecommunications/electronic equipment and components* require timely delivery and freedom from damage rather than low-cost transport. Their main EU export destinations are the UK, Germany and France; movement is principally by ro-ro (in air suspended trailers) with some air freight for high value/urgent shipments;

(h) that transport in the fresh meat end of the *meat products* sector is dominated by the effects of perishability, making speed "absolutely critical". Frozen meat products are less speed-critical. Refrigerated ro-ro transport is generally used;

(i) that cost matters far more than speed to exporters of *basic industrial chemicals*; thus lo-lo (including tank containers for gaseous or liquid products) is generally the mode of choice. Cost can be particularly important for high volume goods such as fertilisers.

General observations on Table 1 include that: (a) the above sectors are judged to be representative of most exports (b) transport requirements are significant influences on cost, quality (through damage, perishing, obsolescence etc.) and delivery standards (delays, inventory costs) of goods; the exporter must find the optimum position for the commodity in question on the cost/quality/delivery "triangle" (c) the three principal cost components of a supply chain are transport cost, inventory cost and information cost; inventory cost is clearly related to transport cost (through, for instance, the greater need to hold stocks where the transport element in the chain is less reliable); information cost is also seen by TPRI as related to the other two elements (d) transport activity is only one part of a chain of activities (referred to as a *supply chain* for materials/components inbound to the manufacturer and a *value adding chain* for final products outbound to consumers) including purchasing, warehousing and distribution activity; increasingly, the elements of the chain are becoming more closely integrated (e.g. "value-added distribution", where distributors take over responsibility for packaging and perhaps some customisation of products).

The specific issues relating to the determinants of the quality of access (sea/air) services were also considered; this is of interest in the context of modal split (and the choice between routes within a single mode, which here probably more closely resembles mode choice than conventional assignment). Table 2 presents a summary of the characteristics affecting access transport quality and the factors which, in turn, shape them.

KPMG and CHL (1990) investigated influences on modal split in several sectors of the access freight market. Amongst their observations were; that the choice between ro-ro and lo-lo surface modes is generally made by the exporter (KPMG and CHL, 1990); that ro-ro predominates on shorter sea routes and lo-lo on longer (because lo-lo's longer handling times are less significant, the longer the route). (KPMG and CHL, 1990); that accompanied ro-ro is chosen mainly for high value or perishable goods, owing to its high security, good time-keeping and shorter port transit times compared with unaccompanied services, but that these advantages were set to decline somewhat with the removal of customs barriers and the stricter enforcement of tachograph regulations; that the factors determining choice between direct and "landbridge" (via Britain) ro-ro shipment to Continental Europe are destination (direct route preferred for French, Spanish and Italian destinations), service level (low capacity on direct routes, and inability to economically expand it due to peaking patterns), cost (landbridge nearly 25% more expensive for French destinations) and time (significantly less, to Belgium and points east, by landbridge) (KPMG and CHL, 1990).

The National Institute for Transport and Logistics (NITL) (1999) carried out a survey of Irish firms' logistical requirements, based on a sample of 104 companies in business sectors comparable to those identified in the previous TPRI study described above. Figure 2 shows the range of customer services (types of delivery) typically required by firms. Figure 3 shows how different attributes are valued in the selection of a carrier, a vitally important aspect of modal split modelling. Finally, Figure 4 summarises the principal destinations of exports.

Table 3 shows how the Standard Transport Nomenclature Commodity (NSTR) classifications utilised by the original statistics were transformed to STEMM classifications. The STEMM classifications run down the table and the NSTR across; reading across from any STEMM classification, the coefficients in the cells of the table indicate what proportion of each NSTR category was assigned to that STEMM category. These proportions were calculated from general trade data (CSO, 1993).

Once Ireland's total imports and exports in STEMM format for the years 1986-1992 inclusive had been generated by the above method, the next step was to calibrate a regression model on these data. A simple linear regression was used, based on GDP (at 1993 prices) by sector (agricultural/industrial/services), with the best approximation to the commodity's producing sector being used to generate exports and a similar approximation to the consuming sector to generate imports. Table 4 indicates the GDP sectors utilised for the various commodities. Table 5 provides a concise summary of the calibration process. It can be seen that the r^2 values obtained are generally quite satisfactory, though their importance should not be exaggerated in view of the approximate nature of the transformation between commodity classifications.

Following this, the total Irish imports and exports for 1995 (this time including Northern Ireland) were generated. They were then disaggregated two-dimensionally by the share of Irish GDP in the relevant sector produced by each region of the island (8 planning regions of the Republic, plus Northern Ireland) and the share of "rest of Europe" GDP in that sector produced by each zone in the remainder of the continent. This led ultimately to the generation of a matrix for each commodity. These matrices were then assigned to the modified Scan-Link network using STAN.

VALIDATION

There was insufficient information available to attempt a validation of true statistical worth. In the end, validation was confined to comparing actual and modelled volumes for freight traffic through a number of ports. Dublin/Dún Laoghaire (considered as one unit), Rosslare, Waterford and Cork were chosen; in each case, ro-ro, lo-lo and bulk traffic were considered, except for Rosslare (ro-ro only) and Waterford (no ro-ro). Thus, a total of eighteen traffic figures (i.e. split into import and export) could be compared. Initial experiments showed a disappointing r^2 value of 0.16, with a distinct tendency to overestimate lo-lo traffic at the expense of ro-ro. Modification was therefore indicated; this took the form of manipulation of the generic unit cost values for the various modes and addition of port-specific penalties where appropriate. After fifteen iterations, the best value that could be achieved for r^2 was 0.58. Table 6 below shows the results in detail.

Additionally, a qualitative comparison was conducted between the findings of TPRI (1995) and those emerging from the freight demand model. The results are indicated in Table 7 below.

The results achieved are generally acceptable; however, a loss of accuracy is apparent in some areas where the TPRI commodities obviously account for only a very small portion of the STAN ones, particularly where several TPRI categories with conflicting requirements make up a STAN commodity. Problems of this nature are inevitable in freight modelling, where the classification of commodities is critical to the replication of real-world behaviour.

RESULTS

The initial set of strategic options listed below were tested against the 2020 do-minimum situation (or, in the case of the do-minimum itself, against the 1995 base situation). The strategies were:

Strategy 01: Do-Minimum (Do-Min)

This strategy assumes that the Irish access transport system continues to follow a logical development path, within the constraints of existing technology, and taking account of the likely trends in the demand for such transport. It incorporates road and rail improvements already planned or otherwise likely, along with evolutionary development of the air and sea networks. The strategy is assigned a net capital cost of zero, as the baseline to which other strategies refer. Naturally, there will be capital costs associated with upgrading and fleet renewal, if the present situation is taken as the baseline.

Strategy 02: Air/Sea, High Investment (ASHI)

This strategy is based on the assumption that the current dominance of sea and conventional air transport in the Irish access market reflects an optimal state of affairs. The best means of dealing with congestion and other problems in the existing system is therefore to invest in additional ports and airports, supplemented by an intensification of services. Some use is made of new technology (ultra-high-speed ferries) within the overall framework of air and sea transport.

Elements of this strategy are: (a) a second Dublin airport located on southwest of city, capital cost of approximately €400 million involved (b) enhanced low-cost airline services, involving approximately €1,496 million of expenditure on additional aircraft over thirty years. (c) a new high-capacity subsidised air freight service ("air bridge") providing links from Irish airports to London and Brussels, involving €5,000 million in aircraft capital costs (over thirty years) (d) a new ro-ro port at Loughshinny (40 miles north of Dublin), cost €200 million (e) enhanced high-speed sea freight services, net additional vessel capital cost of €4,072 million (f) introduction of ultra-high-speed ferries, at a capital cost of roughly €600 million (including provision for terminal improvements) (g) upgraded Dublin-North West road link, cost €1,250 million (h) rail links to Shannon and Belfast International airports, capital cost approximately €220 million (i) rail freight improvements in Ireland, capital cost €136 million (j) piggyback rail services from Holyhead to London and Lille, capital investment of about €625 million involved. The net undiscounted capital cost of this strategy is approximately €16,617 million.

Strategy 03: Air/Sea, Managed Demand (ASMD)

This strategy is based on the assumption that the current dominance of sea and conventional air transport in the Irish access market is optimal, but that the spatial balance of traffic on the relevant networks and their inland feeder systems (particularly the national road network), and the pricing and management of the system, are not. It therefore proposes extensive development of a decentralised access transport network, with a large number of routes from peripheral areas relieving pressure in Dublin and elsewhere. Pricing reform is used to support the aim of decentralisation and also to maximise the sustainability of the system through the internalisation of external costs. Capital investment is minimised as far as possible. Elements of this strategy are (a) imposition of taxes on all modes such that external costs are internalised (b) surcharges on passengers passing through Dublin Airport and freight through Dublin Port (c) significant improvements to the Irish regional airport system, including a new airport near Athlone (centre of Ireland), relocation of Galway airport, expansion of Waterford airport and minor improvements to other regional airports, total capital cost €93 million (d) extension of air services from regional airports, with cutbacks in services from other airports (especially Dublin), net capital cost of additional aircraft €1,803 million (e) development of Drogheda and Arklow ports, at total capital cost of €200 million (f) a less centralised pattern of shipping services; net capital cost of additional vessels €1,665 million (g) upgraded Dublin-North West road link, cost €1,250 million (h) upgraded Belfast-Derry-Sligo-Galway-Shannon-Limerick-Waterford-Rosslare road link, cost €2,600 million (i) rail links to Shannon and Belfast International airports, capital cost €220 million (j) upgraded Galway-Shannon-Limerick-Waterford-Rosslare rail link, cost €100 million (upgrade between Limerick and Galway already included in cost of Shannon rail link) (k) extensive upgrading of rail links from Dublin Port; capital cost €476 million. The net undiscounted capital cost of this strategy is approximately €8,407 million.

Strategy 04: Fixed Link (FL)

This strategy is based on the assumption that only the construction of a fixed rail link between Dublin and Holyhead, with supporting works to the road and rail systems, will provide an efficient, sustainable access transport system in the long term. Elements of this strategy are (a) a rail immersed tube tunnel between the Dublin and Holyhead areas; capital cost €22,000 million

(b) electrification and upgrading of the North Wales Coast main line; costs included in above (c) upgrading of roads around the terminals and of the Dublin-North West Ireland and Holyhead-North West England links; capital cost €1,666 million (d) shuttle train services conveying vehicles through the tunnel; capital costs included in tunnel costs (e) high-speed train services (assuming a new high-speed railway between London and the West Midlands) linking Dublin to Liverpool, Manchester, Birmingham, London, Paris and Brussels; capital cost of rolling stock approx. €1,200 million (f) piggyback rail services from Dublin to London and Lille; capital investment of about €650 million involved (g) through freight trains from Ireland to the south of England and mainland Europe; capital cost €60 million for additional locomotives (h) a scaled-down air and sea network, capital cost saving €1,130 million on ships and €2,730 million on airliners. The net undiscounted capital cost of this strategy is approximately €21,332 million.

Demand Levels and Modal Split Results

Demand information and modal splits were directly output by STAN. Cost calculations were made by generating matrices of zone-to-zone costs in STAN and making further calculations (weighting costs for modal split, allowing for generated traffic etc.). Emissions and external costs were derived from a spreadsheet analysis of the demand data.

Table 8 illustrates the results testing in terms of freight demand. The table provides the following information; total demand in tonne-kilometres (t-km), and as a percentage of the 1995 base demand and 2020 do-minimum demand; demand for transport by mode (again expressed in t-km); modal split (percentage of t-km represented by the relevant mode).

From Table 8 it can be seen that total demand measured in t-km will approximately double over the period 1995-2020 and that total demand remains fairly constant across the range of strategies; this is to be expected, given that transport costs do not feed into the generation of freight flows. In the do-minimum case, the principal mode split trend is a movement away from traditional shipping modes towards rail (due to development of the Channel Tunnel) and fast ferries. A high investment strategy would produce very little in the way of freight mode shifts. It can be noted also that the enhanced and subsidised air freight system incorporated in this strategy is not successful in attracting traffic. Under the managed demand strategy, the primary shifts are away from fast ferries (because of their high external costs) and rail (because bulk shipping has lower external costs) and towards lo-lo and bulk shipping (due to low external costs) and road haulage (which is probably a reflection of longer road hauls resulting from policies designed to encourage the use of peripheral ports in Ireland). This last result may be considered counter-productive. Predictably, a strategy incorporating a (rail) fixed link leads to a shift towards rail at the expense of road and the various sea modes. The managed demand strategy gives the lowest road and (jointly with the high investment strategy) highest rail modal share.

Further results

This section deals with tendencies which have been observed through the graphical output functions of STAN, but which may be obscured in the aggregate demand and modal split results listed above. In particular, it aims to provide a spatial context for the results by drawing attention to divergences between different parts of the study area, which the modal split model could not do without extensive and complex modification to accommodate separate link classes for each sub-area.

The 2020 do-minimum exhibits the following changes from the 1995 base; truck traffic rises on the main Irish radial routes, across most of Britain and on the northwest edge of the European mainland, but falls elsewhere; rail freight traffic generally increases; there is a moderate general decrease in lo-lo freight traffic; ferry traffic rises on most routes, but with a shift from conventional towards fast ferries.

Relative to the do-minimum, the high investment strategy differs as follows; truck traffic increases in the north and west of Ireland, southeastern England and a corridor from the English Channel towards Germany. It decreases in the rest of Ireland, Wales, Scotland, the north of England and the English Channel coastal areas of the European mainland; truck traffic in the Dublin area generally decreases; rail freight traffic increases except on a corridor from northwestern England via the Channel Tunnel towards Paris and Germany, where it decreases; the only noticeable change in lo-lo traffic patterns is a decline on short Irish Sea crossings such as Dublin-Liverpool; there is a general decrease in bulk shipping traffic; fast freighter services show a marked increase in use; ferry freight traffic generally decreases.

The managed demand strategy, on the other hand, has the following characteristics (again relative to 2020 do-minimum); truck traffic declines on radial Irish routes, across most of Britain and in the northwest of mainland Europe; however, it rises on Irish circumferential routes and in more remote parts of Europe; truck traffic declines, but car traffic increases, in inner Dublin; rail freight traffic rises in Ireland but outside Ireland, it is generally reduced, though freight traffic rises in most of Britain; lo-lo freight traffic increases except on short Irish Sea crossings such as Dublin-Liverpool; bulk sea freight rises except along the west coast of Ireland and the east coast of Britain; ferry freight traffic generally declines; air traffic decreases.

In the fixed link strategy, the following are observed; truck traffic increases on links along the south and east coasts of Ireland and from Dublin to the west and northwest, declining elsewhere, outside Ireland, it rises in peripheral areas of Europe but falls in more central areas (e.g. Britain and northern France); a decline in truck traffic, within central Dublin; rail freight traffic increases in Ireland and most of Britain, but individual links in the rest of Europe show both increased and reduced traffic, in no apparent pattern; many bulk sea links- primarily those serving minor ports on the west coast of Ireland and the east and west coasts of Britain- show a slight decrease in demand, though demand on the remainder of the network is unchanged; lo-lo freight traffic rises on longer routes and falls on shorter ones; ferry freight traffic generally declines; air traffic declines across almost all routes; the fixed link and its associated rail services are used quite heavily, particularly the truck-carrying shuttle trains, through rail freight services and the Dublin-London and Dublin-Manchester high-speed rail services.

Emission Results

Table 9 presents the results of the emissions analysis of the strategies. Calculations are made for six individual substances: carbon dioxide (CO_2), oxides of nitrogen (NO_x), sulphur dioxide (SO_2), volatile organic compounds (VOC), carbon monoxide (CO) and particulates (PM_{10}) using data from Waters (1992). From Waters, bulk operations, container haulage and the movement of semi-finished goods lie at the bottom of the range in terms of energy consumption, around 0.7MJ/t-km. Finished goods require around 0.8 MJ/t-km and parcels 0.9MJ/t-km. The very highest values are for consumer product haulage (1.6MJ/t-km) and components delivery to factories (2.0MJ/t-km). SINTEF et al (1998) cite an emission level of 1.4 kg CO^2/km for an articulated truck corresponding (for a payload of 25t) to roughly 0.73MJ/t-km. For rail freight, Waters (1992) quotes a figure of 0.6MJ/t-km for bulk traffic, 0.7 for single-consignment point-to-point trainloads, 1.0 for wagonload traffic (i.e. individual wagons are picked up and dropped off at multiple points) and 0.9 for container trunk haulage. These figures would appear to indicate that rail freight only possesses a conclusive advantage over road in terms of energy consumption for bulk haulage and trainload freight. It must, however, be taken into account that the road figures are for fully loaded vehicles whereas the rail data is an average. Furthermore, Irish figures based on the locomotive fuel consumption data referred to above (Nautical Enterprise Centre, 1998) would suggest that, at the average payload cited by the same source of 400t/train, a value of 0.27MJ/t-km is attained. This is more in line with other past evaluations of rail freight energy use. SINTEF et al. (1998) claim a figure of 0.5kg CO_2/40 foot unit-km, equivalent to about 0.32MJ/t-km. Mid-range energy consumption figures from the data described above are used in conjunction with the information on emissions characteristics from INRETS (1999) for road transport.

From Table 9, it can be observed that: (a) CO_2 and SO_2 emissions roughly double in the do-minimum relative to 1995; however, other emissions (and total air pollutants) rise by only between 4% and 50%, significantly less than the growth in transport demand (b) a high investment strategy increases all emissions by between 10% and 50% relative to the do-minimum. Total air pollutants rise by 25% and CO_2 by 20% (c) a managed demand strategy cuts all emissions (except NO_x and CO) by between 2% and 34% and otal air pollutants are reduced by 5% and CO_2 by 2% (d) a fixed link strategy cuts all emissions (except NO_x and CO_2) by between 9% and 28% and total air pollutants are reduced by 9%, but CO_2 rises by 4%

ECONOMIC FACTORS

It was not feasible to carry out a full cost-benefit. Instead, the impacts of the various strategies in terms of generalised cost, external cost and taxation have been examined and compared with their capital costs. Table 10 summarises the results of this analysis. The items included in the table are (a) passenger benefits: reduction (positive) or increase (negative) in passenger generalised cost (inclusive of taxes), as output by STAN, between do-minimum and strategy in question. (b) freight benefits estimate 1: change in freight generalised costs, (c) freight benefits estimate 2: change in freight generalised costs for an "average" product (metal products), factored up to total freight volumes (this alternative approach was taken in an attempt to shed light on the reasons for large freight disbenefits accruing to most of the do-something options in estimate 1; however, the position was not fundamentally changed by the alternative approach to estimation) (d) External benefits: changes in external costs calculated from demand and modal split data (e) taxation/charging benefits: changes in net cash flow to government (tax increases positive, subsidy increases negative). (f) net benefit stream: sum of passenger, freight, external and taxation/charging benefits (this includes passenger as well as freight) (g) capital cost: (h) net benefit stream/capital cost: an indicator of cost-effectiveness. None of these figures is discounted and (apart from capital cost) they represent a single year in each case.

It can be noted that (a) freight benefits are generally negative (increased generalised cost), as are the resulting net benefit streams (b) external benefits are generally positive (c) only the managed demand strategy produces any change in the tax/subsidy field, and this is positive (i.e. tax income exceeds subsidy expenditure) (d) although the picture varies depending on how benefits are calculated, generally the high investment strategy appears most cost-effective. However, the managed demand strategy also shows up well. It must be noted that (by the rules utilised here) no strategy produces positive benefit flows across all alternative calculations.

A further analysis was done to see the impacts on particular regions within Ireland. Results for the following regions are presented in Table 11: the Border (border with Northern Ireland) Mid West (BMW) region, South (S) and East (E), Northern Ireland (NI). The business travel purpose includes passenger traffic as well as freight so in the context of this paper perhaps the first part of the table is of most interest.

CONCLUSIONS

The approach chosen seems to have led to a model which was generally capable of replicating conditions in the market, notwithstanding any difficulties identified here. Non-modelling-based methodologies (which were seriously considered in earlier stages of the work) cannot be justified as a serious alternative to modelling for the work involved. The methodology used for generation of freight flows appears to be the best and consistent with the limited data available.

The number, scope and characteristics of the various commodities into which freight traffic is divided was dealt with earlier. In view of the modelling results, an examination has been made of this classification in order to determine whether it might be improved upon in any way. The relevant conclusions are (a) a more detailed approach was developed in outline for purposes of discussion, but proved to pose excessive difficulties. These resulted primarily from the increase in model and calibration requirements associated with a transition from twelve to at least twenty commodities (b) consideration was also given to amendment of the weights attached to the various cost components in respect of each commodity, to improve accuracy and better reflect the position in the Irish access market.

The conclusions from the strategies tested can be summarised as follows: (a) the do-minimum strategy has advantages in terms of feasibility but does not perform well on other criteria, though it is not the worst-performing strategy overall (b) the "high investment" strategy is successful in reducing user costs and achieving an equitable balance of costs between regions and user groups, but has few other benefits. It is costly and has major negative environmental impacts (c) the "managed demand" strategy has significant environmental benefits, but is generally not the best strategy in this area. Although its capital costs are low, it significantly increases user costs. It is not an ideal solution, but appears to represent a better way to build on the strengths of existing modes than the "high investment" approach (d) the "fixed link" strategy is very costly, has negative impacts on the marine environment, but reduces emissions significantly. In more generic terms, the results indicate that an "ideal" strategy would combine some form of demand restraint and selected infrastructural improvements in some modes.

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Figure 1 Unitised Freight Traffic Through Republic of Ireland Ports

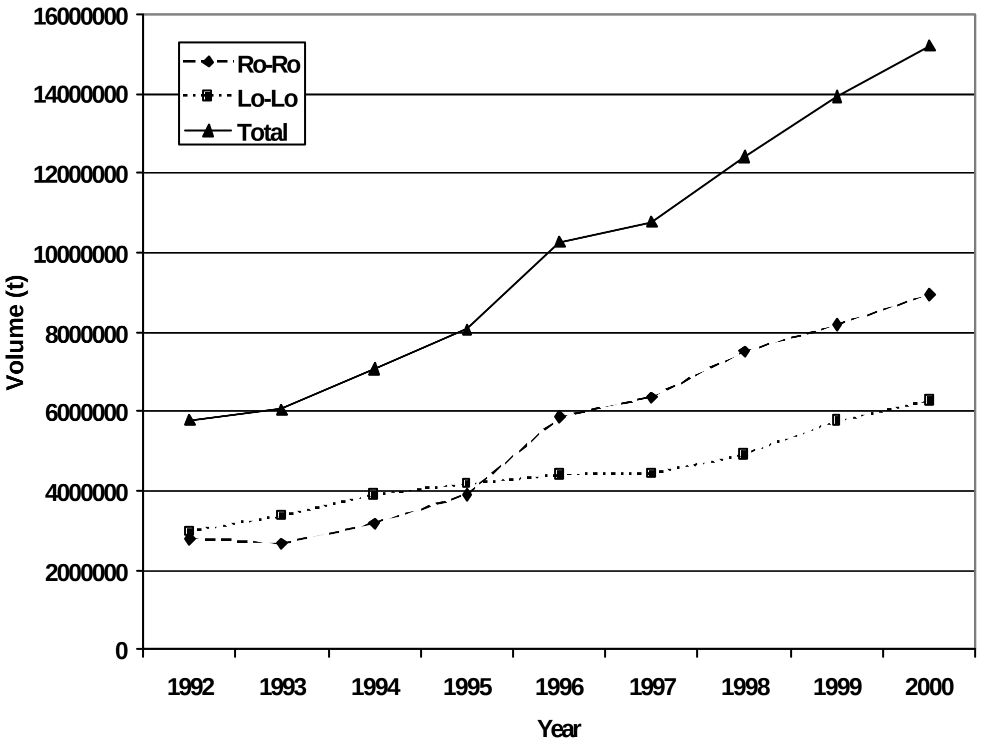

Figure 2 Customer Services Required by Irish Industry (NITL, 1999)

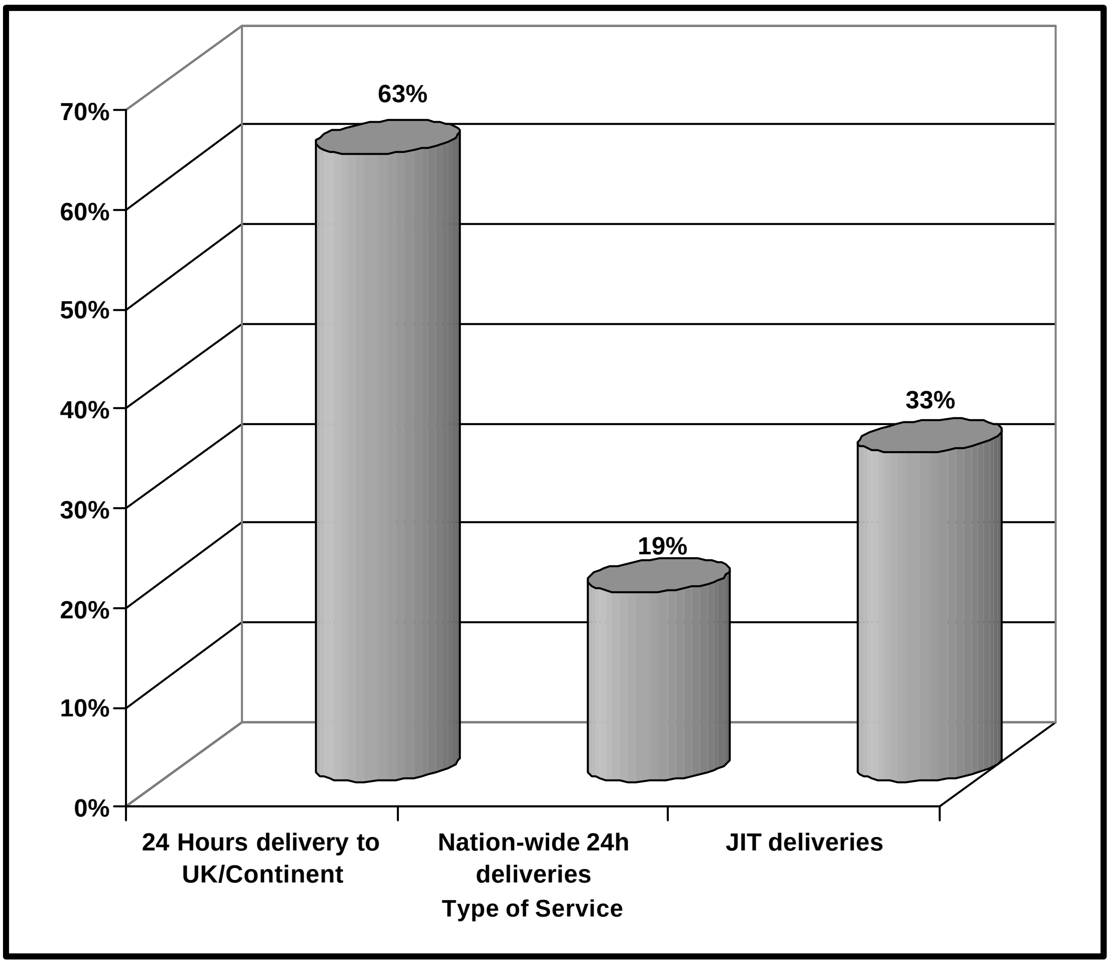

Figure 3 Valuation of Attributes (NITL, 1999)

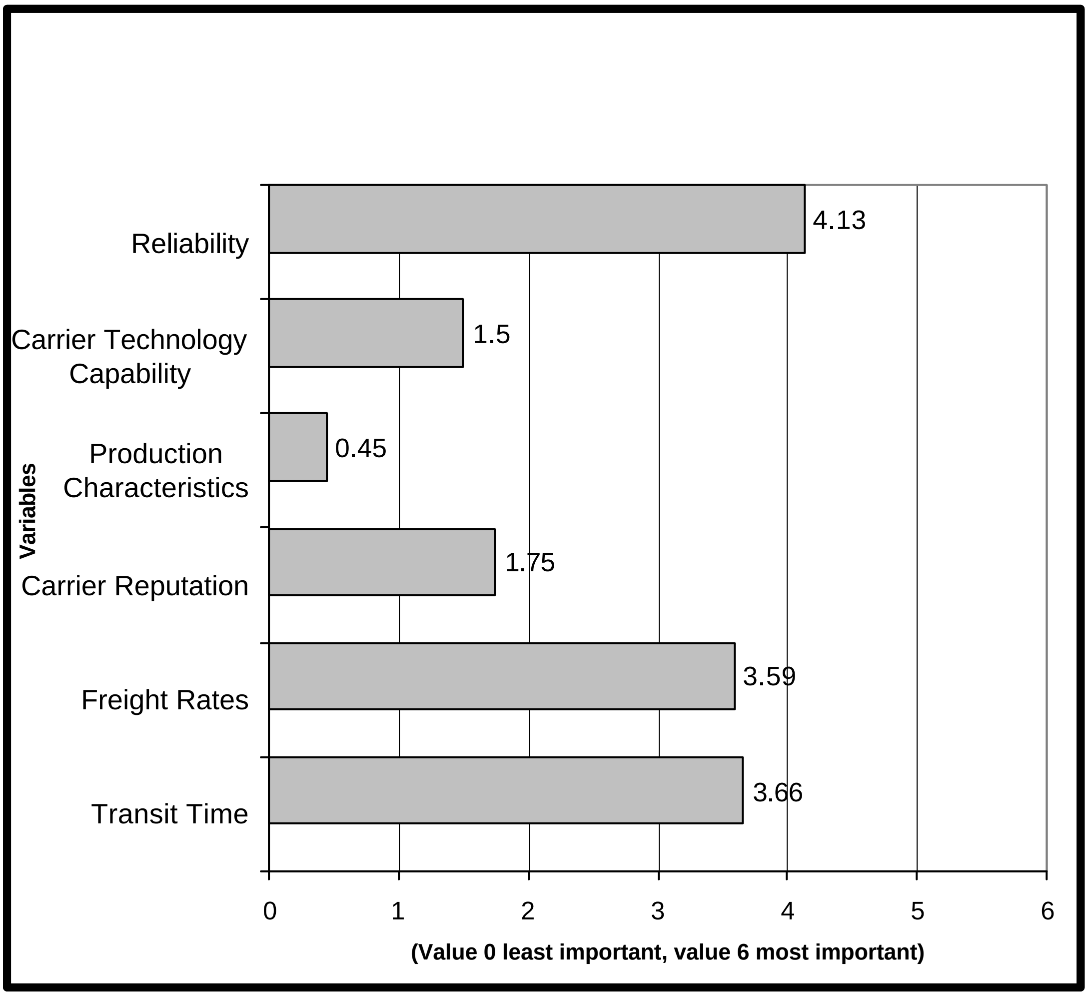

Figure 4 Principal Destinations (NITL, 1999)

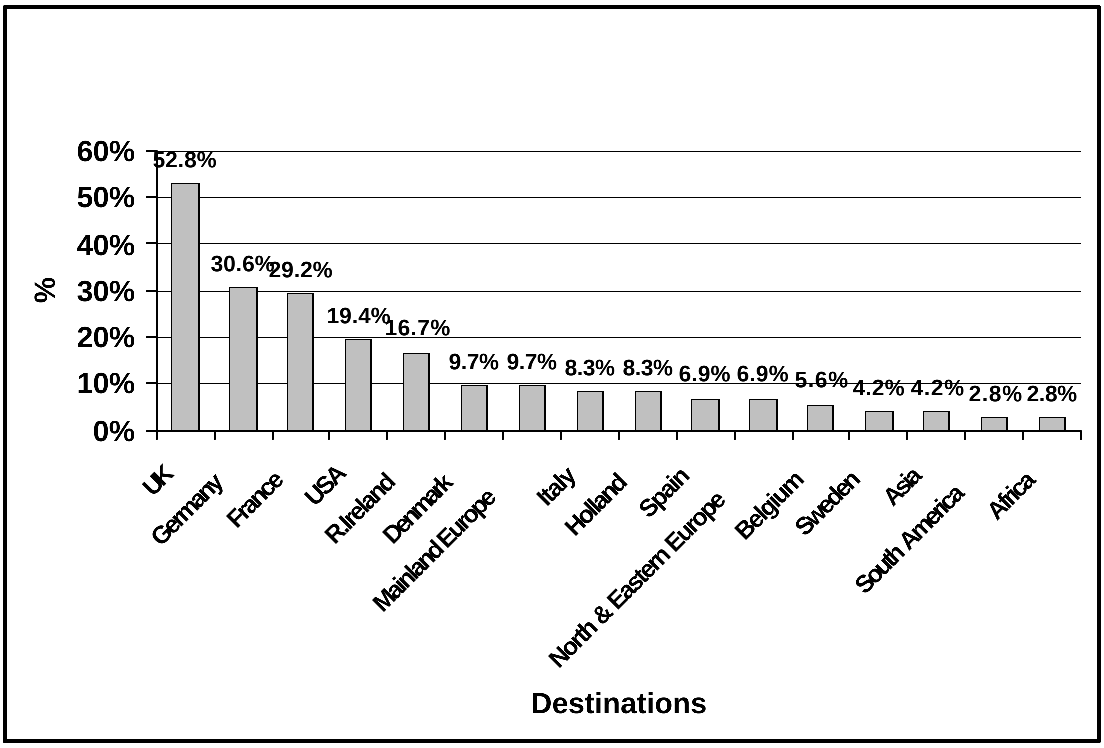

Table 1. Transport Characteristics of Major Export Sectors (TPRI, 1995)

Sector	Transport Usage			Importance of transport attributes					
	Ro-Ro	Lo-Lo	Air	Dir/Grp[1]	Cost	Speed	Timing	Vehicle	VAD[2]
Office computers etc.	High	Low	High	D+G	Low	High	High	High	High
Pharma-ceutical	Medium	High	Medium	G	Low	Medium	Medium	High	Low
Dairy	Medium	High	Low	D	High	Low	Low	High	Low
Service industry (software)	High	Low	Low	D	Low	Low	Low	High	High
Other food	Medium	High	Low	D	High	Low	High	Medium	Low
Auto parts	Low	High	Low	D	High	Medium	High	Medium	Medium
Healthcare/ medical	High	Medium	Low	G	Low	Medium	High	Low	Low
Telecom/ electrical	High	Low	Medium	D	Low	Low	High	High	Low
Meat products	High	Low	Low	D	High	High	High	High	Possibly
Basic industrial chemicals	Low	High	Low	D	High	Low	Low	Low	Low

[1] Direct shipment as a single consignment or groupage, i.e. combination of consignments in a single vehicle.
[2] Value Added Distribution, i.e. the carrying out of various packaging, customisation etc. tasks as part of the distribution process.

Table 2 Determinants of Access Transport Quality (TPRI, 1995)

Characteristic	**Influencing factors**
Access route availability	Location of ports/airports Configuration of services
Price of sea/air crossings	Capital cost of vehicles Utilisation Route length Operating costs Other operational considerations
Speed of transport service	Vehicle technology Loading/unloading efficiencies Terminal throughput times
Service frequency	Vehicle size Traffic volume
Access transport reliability	Technical efficiency Operational precision Weather effects Air traffic control delays Vulnerability to service interruptions (e.g. strikes) Market structure effects (e.g. exit from market, monopoly)

Table 3 NSTR -STEMM Commodity Transformation

Commodity number	*Commodity name*	Ag. Prod./ live animals	Food-stuffs/ fodder	Solid mineral fuels	Petroleum products	Ores/ metal waste	Metal products	Crude/ manuf. minerals	Fertilisers	Chemicals	Machinery etc.
1	Food/live animals	0.75	0.5								
2	Beverages/ tobacco		0.25								
3	Crude inedibles	0.25				1		0.5			
4	Mineral fuels			1	1						
5	Animal/ Veg. oils		0.25								
6	Chemicals								1	1	
7	Paper/ Paper-board										
	Metal products						1				
9	Manuf. goods							0.5			0.25
10	Machine-ry										0.25
11	Misc. manuf. articles										0.25
12	Valuable machinery etc.										0.25

Table 4 Production/Attraction Variables for Freight Traffic

Commodity number	*Commodity name*	**Production variable**	**Attraction variable**
1	Food/live animals	Agricultural GDP	Services GDP
2	Beverages/tobacco	Industrial GDP	Services GDP
3	Crude inedibles	Agricultural GDP	Industrial GDP
4	Mineral fuels	Industrial GDP	Industrial GDP
5	Animal/veg. oils	Agricultural GDP	Industrial GDP
6	Chemicals	Industrial GDP	Industrial GDP
7	Paper/paperboard	Industrial GDP	Services GDP
8	Metal products	Industrial GDP	Industrial GDP
9	Manuf. goods	Industrial GDP	Services GDP
10	Machinery	Industrial GDP	Industrial GDP
11	Misc. manuf. articles	Industrial GDP	Services GDP
12	Valuable machinery/ manuf. articles	Industrial GDP	Services GDP

Table 5 Freight Calibration Results

Commodity number	*Commodity name*	**Exports**			**Imports**		
		Intercept	Slope	R^2	Intercept	Slope	R^2
1	Food/live animals	1225	0.2	0.21	94	0.11	0.77
2	Beverages/tobacco	90	0.03	0.74	-548	0.06	0.88
3	Crude inedibles	727	0.18	0.58	123	0.06	0.77
4	Mineral fuels	170	0.05	0.54	7066	0.08	0.24
5	Animal/veg. oils	-20	0.15	0.73	173	0.03	0.93
6	Chemicals	-247	0.11	0.84	1368	0.16	0.89
7	Paper/paperboard	22	0.01	0.81	-388	0.03	0.86
8	Metal products	-25	0.02	0.67	155	0.02	0.69
9	Manuf. goods	221	0.04	0.57	-1998	0.16	0.9
10	Machinery	3	0.01	0.9	-575	0.05	0.97
11	Misc. manuf. articles	3	0.01	0.9	-575	0.05	0.92
12	Valuable machinery/ manuf. articles	3	0.01	0.9	-575	0.05	0.92

Table 6 Quantitative Freight Validation Results

Port	Mode	Import/Export	Modelled	Actual
Rosslare	ro-ro	export	1028	562
Rosslare	ro-ro	import	1656	569
Waterford	lo-lo	export	28	631
Waterford	lo-lo	import	44	635
Waterford	bulk	export	697	116
Waterford	bulk	import	1552	394
Cork	lo-lo	export	232	316
Cork	lo-lo	import	455	215
Cork	ro-ro	export	0	40
Cork	ro-ro	import	0	82
Cork	bulk	export	1285	2309
Cork	bulk	import	3068	4141
Dublin Bay	lo-lo	export	383	1053
Dublin Bay	lo-lo	import	1001	1325
Dublin Bay	ro-ro	export	1088	1155
Dublin Bay	ro-ro	import	3439	1487
Dublin Bay	bulk	export	502	558
Dublin Bay	bulk	import	3288	3324

Table 7 Qualitative Freight Validation Results

TPRI commodity	STAN commodity	TPRI ro-ro use	STAN ro-ro use	TPRI lo-lo use	STAN lo-lo use
Office computers etc.	Valuable machinery/ manuf. articles	High	High	Low	Medium
Pharmaceutical	Chemicals	Medium	Medium	High	Low
Dairy	Food/live animals	Medium	High	High	Low
Service industry (software)	Misc. manuf. articles	High	High	Low	Medium
Other food	Food/live animals	Medium	High	High	Low
Auto parts	Manuf. goods	Low	Medium	High	Low
Healthcare/ medical	Valuable machinery/ manuf. articles	High	High	Medium	Medium
Telecom/ electrical	Valuable machinery/ manuf. articles	High	High	Low	Medium
Meat products	Food/live animals	High	High	Low	Low
Basic industrial chemicals	Chemicals	Low	Medium	High	Low

Table 8 Freight Demand and Modal Split

Strategy		1995 Base	01Do-Min	02 ASHI	03 ASMD	04 FL
Total freight transport (t-km)		93,599,976,000	191,158,786,000	189,045,629,000	191,847,716,000	189,353,134,000
Total as % 1995		100%	204%	202%	205	202
Total as % 2020 do-min		49%	100%	99%	100%	99%
Freight transport by mode:						
Road	Total	19,571,078,000	35,444,324,000	32,995,918,000	53,789,536,000	38,185,920,000
	Share	21%	19%	17%	28%	20%
Rail	Total	22,265,862,000	94,110,048,000	93,303,928,000	15,535,162,000	79,884,912,000
	Share	24%	49%	49%	8%	42%
Piggyback	Total	0	1,450,147,000	1,495,109,000	102,111,000	1,040,995,000
	Share	0%	1%	1%	<1%	1%
Ferry	Total	1,753,047,000	74,654,000	66,019,000	66,669,000	58,070,000
	Share	2%	<1%	<1%	<1%	<1%
Lo-lo	Total	1,225,909,000	998,282,000	15,490,000	27,443,116,000	3,992,279,000
	Share	1%	1%	<1%	14%	2%
Bulk shipping/ inland waterway	Total	48,784,076,000	53,755,184,000	51,514,480,000	94,868,712,000	69,775,136,000
	Share	52%	28%	27%	49%	37%
Fast ferry	Total	0	5,326,147,000	4,771,025,000	42,410,000	0
	Share	0%	3%	3%	<1%	0%
Fast freighter	Total	0	0	4,883,660,000	0	0
	Share	0%	0%	3%	0%	0%
Air freight	Total	0	0	0	0	0
	Share	0%	0%	0%	0%	0%

Table 9 Emissions

Pollutant	1995 Base	01 Do-Min		02 ASHI		03 ASMD		04 FL	
	t	t	% 1995	t	% 01	t	% 01	t	% 01
CO_2	7,318,181	15,419,011	211	18,531,837	120	15,142,589	98	16,079,679	104
NO_x	102,073	106,569	104	124,000	116	111,522	105	109,638	103
SO_2	35,591	59,431	167	88,172	148	50,996	86	42,801	72
VOC	6,292	9,012	143	9,886	110	5,983	66	8,585	95
CO	14,328	14,924	104	17,145	115	16,563	111	12,115	81
PM_{10}	9,933	14,826	149	16,381	110	10,152	68	13,248	89
Total air pollutants	168,217	204,672	122	255,584	125	195,216	95	186,387	91

Table 10 Summary of Costs and Benefits (€)

	02 ASHI	03 ASMD	04 FL
Freight benefits estimate 1	109,102,000	-32,000,000,000	-18,000,000,000
Freight benefits estimate 2	-26,731,500	-14,000,000,000	-8,096,680,000
External benefits	-813,579,432	606,379,861	361,186,245
Taxation/charging benefits	0	3,668,198,340	0
Net benefit stream estimate 1	-547,668,432	-29,224,944,800	-17,521,553,760
Net benefit stream estimate 2	-683,501,932	-8,225,898,799	-7,618,233,755
Capital cost	16,617,000,000	8,407,000,000	21,730,000,000
Net benefit stream estimate 1/ capital cost	-0.033	-3.476	-0.806
Net benefit stream estimate 2/ capital cost	-0.041	-0.978	-0.351

Table 11 Benefits/Unit Cost by Region and Travel Purpose

Strategy	02 ASHI	03 ASMD	04 FL	05 BA
BMW freight	+0.00093	-1.73141	-1.05273	-0.48002
S&E freight	+0.006865	-1.72028	-0.97864	-0.46422
NI freight	+0.008109	-1.97284	-1.13073	-0.60581
BMW business	+0.013322	+0.010262	+0.000496	+0.000467
S&E business	+0.008107	+0.004196	-0.00595	-0.00579
NI business	+0.003074	-0.00054	-0.00576	-0.00763
BMW non-business	+0.045747	-0.09509	+0.046267	-0.02143
S&E non-business	+0.007302	-0.10803	+0.033304	-0.04248
NI non-business	+0.017828	-0.12635	-0.01332	-0.06166